PATENT ABSTRACTS OF JAPAN

(11)Publication number : 10-290049
(43)Date of publication of application : 27.10.1998

(51)Int.Cl. H01S 3/18
H01L 29/06

(21)Application number : 09-096918
(22)Date of filing : 15.04.1997

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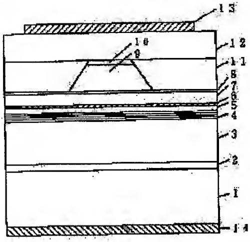
(54) SEMICONDUCTOR LASER ELEMENT

(57)Abstract:
PROBLEM TO BE SOLVED: To set properly the hole carrier concentration level of P-type impurities in a P-type InGaAsP layer, which is introduced in a P-type AlGaZnP optical waveguide layer in the vicinity of the active layer of a semiconductor laser element, and to inhibit a diffusion of the impurities.

SOLUTION: A P-tape InGaAsP layer, which is small in diffusion constant and in which the hole carrier concentration level of P-type impurities can be set in the range of 5 × 1017 to 1 × 1018cm-3 without diffusing the carrier concentration of the impurities, is introduced in a P-type AlGaInP optical waveguide layer in the vicinity of an active layer 4 of a semiconductor laser element. As the forbidden band width of the InGaAsP layer becomes narrower than that of the optical waveguide layer, a multiperiodic superlattice structure is constituted of the InGaAsP layer as a thin film layer.



* NOTICES *

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CLAIMS

[Claim(s)]
[Claim 1]Into a semiconductor crystal layer which makes a phosphorus system a subject as a V group element, a semiconductor crystal layer which introduced an arsenic system into V group element is provided, A semiconductor laser element having provided a semiconductor layer whose V group element is an arsenic system as a multi-cycle superstructure which consists of thin film layers as a thin film layer which produces a quantum size effect.
[Claim 2]In a semiconductor layer whose V group element is an arsenic system from inside of a semiconductor layer which has provided a semiconductor crystal layer which introduced an arsenic system into V group element into a semiconductor crystal layer which makes a phosphorus system a subject as a V group element, and made V group element a phosphorus system, The semiconductor laser element according to claim 1 having set up carrier concentration of an impurity highly.
[Claim 3]III Material which makes a phosphorus system a subject is used for V group element among -V fellows mixed-crystal semiconductor materials, Double heterojunction structure which consists of a semiconductor light active layer and a semiconductor lightguide which sandwiches it is formed, V group element provides multi-cycle superlattice layers [near / above-mentioned / the active layer in the above-mentioned lightguide which is a phosphorus system], The semiconductor laser element according to claim 1 or 2 having formed a superlattice well layer at least by a layer which introduced an arsenic system into V group element, and having set carrier concentration of an impurity to the above-mentioned superlattice well layer highly rather than the above-mentioned lightguide further.
[Claim 4]The above-mentioned luminescence active layer is provided as distorted multiple quantum well structure which repeated a distortion quantum well layer and a deformation amount child barrier layer, The semiconductor laser element according to claim 3 having doped an impurity to the above-mentioned deformation amount child barrier layer which V group element forms a deformation amount child barrier layer and a light separating confining layer which adjoin a distortion quantum well layer by a semiconductor crystal layer which is an arsenic system, and consists of an arsenic system, or a light separating confining layer.
[Claim 5]The semiconductor laser element according to claim 3 or 4 having set up electron hole carrier concentration which doped an impurity in which a p type conductivity type is shown as an impurity in a layer which was introduced into the above-mentioned lightguide or the above-mentioned luminescence active layer, and which provided V group element as an arsenic system at least, and was activated by an impurity dope.
[Claim 6]Electron hole carrier concentration which doped a p type impurity and was activated is set to a superlattice well layer which constitutes a superstructure established into the above-mentioned lightguide and which made V group element an arsenic system more highly than the above-mentioned lightguide, The semiconductor laser element according to claim 3 or 5 which makes electron hole carrier concentration the range of $3x10^{17} - 1x10^{19}cm^{-3}$, and is characterized by having set it as the range of $5x10^{17} - 5x10^{18}cm^{-3}$ more appropriately.
[Claim 7]By doping a p type impurity to a deformation amount child barrier layer and a light separating confining layer which made V group element an arsenic system in distorted multiple quantum well structure which constitutes the above-mentioned luminescence active layer, Activated electron hole carrier concentration is set as the range of $3x10^{17} - 2x10^{18}cm^{-3}$ more appropriately than the range of

$1x10^{17} - 5x10^{18}cm^{-3}$, The semiconductor laser element according to claim 4 or 6 constituting distorted multiple quantum well structure which has carried out the abnormal-conditions dope.

[Claim 8]The above-mentioned luminescence active layer is used as a distortion quantum well layer and the above-mentioned distortion quantum well layer with compensates distortion multiple quantum well structure by repetition by a deformation amount child barrier layer which has a lattice strain of an opposite sign, The semiconductor laser element according to claim 1 constituting when a distorted interlayer with each middle amount of lattice strains is provided between the above-mentioned distortion quantum well layer and the above-mentioned deformation amount child barrier layer and V group element forms the above-mentioned distorted interlayer by a layer which consists of an arsenic system.

[Claim 9]The semiconductor laser element according to claim 8 having set up electron hole carrier concentration which doped an impurity in which a p type conductivity type is shown as an impurity to a distorted interlayer who consists of an arsenic system provided between the above-mentioned distortion quantum well layer and the above-mentioned deformation amount child barrier layer, and was activated by an impurity dope.

[Claim 10]Electron hole carrier concentration activated by doping a p type impurity to the above-mentioned distorted interlayer is set as the range of $3x10^{17} - 2x10^{18}cm^{-3}$ more appropriately than the range of $1x10^{17} - 5x10^{18}cm^{-3}$, The semiconductor laser element according to claim 9 constituting compensates distortion multiple quantum well structure which has carried out the abnormal-conditions dope.

[Claim 11]A semiconductor laser element given in claims 1-10, wherein the element seeds doped as an impurity in which a p type conductivity type is shown have set up electron hole carrier concentration which is Zn, Mg, or Be and was activated by doping one of elements of these.

[Claim 12]A monocrystal substrate used for providing the above-mentioned lightguide and the above-mentioned luminescence active layer has the plane direction turned off from a field (100), The semiconductor laser element according to claim 1 a range of a plane direction being 5-25.2 degrees from a field (100) more appropriately than the range of 0-54.7 degrees, having set it as 7-16 degrees as optimal range in practice, and having formed it on the above-mentioned monocrystal substrate.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention]This invention relates to a semiconductor laser element suitable for the light source for optical information processing or optical measurement.
[0002]
[Description of the Prior Art]In conventional technology, it is easy to diffuse the p type impurity doped to the lightguide of the semiconductor laser, is in the situation of being further hard to set up desired carrier concentration, and had the problem that an improvement of an element characteristic could not be aimed at. As shown to electronics Letters 1996 year 32 volume 661-662 page (Electronics Letters 1996, 32,661-662) by the conventional example, Zinc is made into an example as a p type impurity, and it is 1.3 micrometers. In the long wavelength semiconductor laser of a belt, p type carrier concentration to a lightguide More than $2x10\ ^{18}cm^{-3}$. If more than $5x10\ ^{17}cm^{-3}$ introduces to an active layer, it will have reported that element characteristics, such as threshold current and differential quantum efficiency, deteriorate.
[0003]
[Problem(s) to be Solved by the Invention]By the above-mentioned conventional technology, in the InP system laser device of a long wavelength region, it is the contents which investigated influence on the element characteristic of the p type impurity which is easy to diffuse, and the result of having evaluated the experimental level of p type carrier concentration which does not influence notably is only described. However, the new technique for controlling diffusion or controlling p type carrier concentration on a high level is not described.
[0004]The purpose of this invention makes reference in the contents about the technique of setting up high carrier concentration to a lightguide or an active layer in order to aim at an improvement of the element characteristic of a semiconductor laser, especially threshold current and temperature characteristics. It is in realizing improvement in an element characteristic by showing a solving means to the technical problem that V group element cannot control the carrier concentration activated by diffusion of the p type impurity by the semiconductor material which consists of a phosphorus system especially easily.
[0005]
[Means for Solving the Problem]This invention describes a means by which V group element solves an aforementioned problem to a semiconductor laser element which mainly comprises a phosphorus system by a mixed-crystal semiconductor. V group element in a semiconductor laser which comprises a phosphorus system. Since it has the feature of being easy to diffuse a p type impurity, electron hole carrier concentration cannot be highly designed with order near the $10\ ^{18}cm^{-3}$, There are restrictions that diffusion of an impurity must set it as a low value of $10\ ^{17}cm^{-3}$ which does not pose a problem on an element characteristic. Since diffusion arises according to outside environment conditions, such as a growing condition, also when p type impurity concentration is a value of $10\ ^{17}cm^{-3}$ order, especially AlGaInP system material used for a semiconductor laser of a short wavelength region requires setting out of very precise carrier concentration.
[0006]For this reason, diffusion is controlled and a diffusing constant of a p type impurity enabled it to

set predetermined carrier concentration as a narrow field using material which consists of an arsenic system of V group element as a small material in this invention. In material which introduced arsenic into V group element, an about double figures diffusing constant of a p type impurity can be made small from a single figure. By adjusting a presentation of arsenic appropriately using AlGaInAsP or GaInAsP system material, while an InP system and forbidden-band width of long wavelength system material double a grating constant also to an AlGaInP system of short wavelength system material greatly, it can introduce.

[0007]To an element, by the ability to set up highly electron hole carrier concentration of a p type lightguide near the active layer, a Fermi level in a valence band can be made high, and a design which increased energy barrier height is attained. According to increase of barrier height of a p type lightguide, leakage of an electron carrier from an active layer can be controlled. In an element characteristic, it was able to make it have been able to reveal a great effect especially to reduce threshold current and to improve temperature characteristics, and the above-mentioned characteristic was able to be raised at least 20 to 30%.

[0008]If the feature of a semiconductor laser element of this invention is indicated from a certain limited aspect of affairs, A laminated structure which repeats and laminates the 1st semiconductor layer and 2nd semiconductor layer is introduced into a portion which has p type conductivity among semiconductor regions (it has a refractive index smaller than an active region) contiguous to an active region which has a luminous region slack active layer or multiple quantum well structure. Although any semiconductor layer is formed by a compound semiconductor layer which consists of group III elements and a V group element, In composition ratio of V group element which constitutes these compound semiconductor layers, the 2nd semiconductor layer contains As (arsenic) of a ratio higher than the 1st semiconductor layer, or the 1st semiconductor layer has the first feature in a place containing P (phosphorus) of a ratio higher than the 2nd semiconductor layer. In a limitation which the 1st semiconductor layer and 2nd semiconductor layer do not make produce a rearrangement by lattice mismatching in each semiconductor layer, it is permitted that the 1st semiconductor layer does not contain As and that the 2nd semiconductor layer does not contain P. It is in p type impurity concentration of the 2nd semiconductor layer of the above being higher than that of the 1st semiconductor layer of the above as the second feature. if it responds to resistance requested from an above-mentioned semiconductor region, it is good even if it does not introduce a p type impurity into the 1st semiconductor layer artificially (what is called -- as undoped).

[0009]Even if these semiconductor layers have a good thing which brings about a quantum size effect and which thickness shall be 10 nm or less desirably from a viewpoint (let a laminated structure be superlattice) and the 2nd semiconductor layer shows a refractive index higher than a luminous region in this case, for example, Since an effectual refractive index to a luminous region serves as a macroscopic value of the whole laminated structure and a direction of a refractive index of a luminous region becomes high, there is an advantage which does not interfere with optical confinement or an optical guide at all. An above-mentioned semiconductor region refers to a light guide layer which a refractive index is higher than a cladding layer or a cladding layer, and is provided in luminous region slippage. An above-mentioned laminating region may be established in an inside of a p type current carrying part, or may be established in a boundary between a p type current carrying part and a undoped part (portion which does not introduce an impurity artificially).

[0010]

[Embodiment of the Invention]This invention is concretely explained from Examples 1 thru/or 6 which showed the desirable embodiment of this invention hereafter, and the related drawing of those.

[0011](Example 1) One example of this invention is described using drawing 1. On the n type GaAs substrate 1 in drawing 1, 0.5 micrometer in thickness. Come out and The carrier concentration 1 - n type GaAs buffer layer 2 of $2x10^{18}cm^{-3}$, 2.0 micrometers in thickness. Come out and by a undoped AlGaInP light separating confining layer and 4 nm in thickness at the n type AlGaInP lightguide 3 of carrier concentration $5x10^{17}$ - $1x10^{18}cm^{-3}$, and 10 nm of 20 nm of thickness one side one side Undoped tensile strain AlGaInP quantum barrier layer two-layer. And the compensates distortion multiple quantum well structure active layer 4 which consists of three layers of undoped GaInP compressive strain quantum well layers at 5 nm in thickness, 0.022 micrometer in thickness. Come out

and by the carrier concentration 2 – the p type AlGaInP lightguide 5 of $4x10^{17}cm^{-3}$, and 1.15 nm of thickness 4 atomic layers Five layers of p type GaInAsP well layers and 1.5 nm of thickness pentatomic layers of carrier concentration $5x10^{17}$ – $1x10^{18}cm^{-3}$. The superstructure high carrier concentration layer 6 and 0.24 micrometer in thickness which come out and consist of the carrier concentration 2 – four layers of p type AlGaInP barrier layers of $4x10^{17}cm^{-3}$ The carrier concentration 2 – the p type AlGaInP lightguide 7 of $5x10^{17}cm^{-3}$, At 0.01 micrometer in thickness, the carrier concentration 5 – $8x10^{17}cm^{-3}$. the p type GaInP etching stopping layer 8 and 1.35 micrometers in thickness. Come out and at the p type AlGaInP lightguide 9 of carrier concentration $8x10^{17}$ – $1x10^{18}cm^{-3}$, and 0.02–0.05 micrometer in thickness the p type GaInP buffer layer 10 of carrier concentration $8x10^{17}$ – $2x10^{18}cm^{-3}$. It grows epitaxially by an organic-metal-vapor-growth (MOCVD) method.

[0012]The outline about the forbidden band an active layer and near the active layer becomes as shown in drawing 2 (a) and (b).

[0013]Next, the stripe mask of a SiO_2 insulator layer is formed by vapor-depositing a SiO_2 insulator layer and passing through photo lithography and an etching process. Using a SiO_2 insulator layer mask, etching removal of the layers 10 and 9 is carried out until it results in the layer 8, and the order mesa ridge stripes of the trapezoidal shape shown in drawing 1 are produced. Then, selective growth of the carrier concentration 1 – the n type GaAs embedding current stricture layer 11 of $3x10^{18}cm^{-3}$ is carried out at 0.6–1.2 micrometers in thickness, After carrying out etching removal of the SiO_2 insulator layer mask, the p type GaAs embedding contact layer 12 of carrier concentration $1x10^{18}$ – $1x10^{20}cm^{-3}$ is grown up at 3–5 micrometers in thickness. After vapor-depositing the p lateral electrode 13 and the n lateral electrode 14, a cleavage scribe is carried out and the element of drawing 1 is obtained.

[0014]According to this example, the electron hole carrier concentration of $5x10^{17}$ – the $1x10^{18}cm^{-3}$ range was able to be made to set up by providing the high carrier concentration layer of an InGaAsP superstructure [near the active layer], without diffusing a p type impurity notably. This is equivalent to a 3 to 5 times as many level as the value in a p type AlGaInP lightguide which was able to be set up conventionally. As compared with the case where electron hole carrier concentration is a $1x10^{17}cm^{-3}$ level, the Fermi level in a valence band can be set up highly, and the energy barrier height of a p type lightguide is made to increase further by about 65 meV from 40meV at least. Since the leakage of the electron carrier from an active layer was controlled, threshold current was reduced and increase of this barrier height enabled it to improve temperature characteristics further. As a result, threshold current and characteristic temperature have been improved 20 to 30%. In this element, it oscillated with the wavelength 680 nm band, and the threshold current of a room temperature is 40–50 mA, and, as for characteristic temperature, 130–150K were obtained. In the reliability trial, at the temperature of 70 **, 40-mW constant optical power operation continued for 5000 hours or more, and it has attained.

[0015](Example 2) Drawing 3 and drawing 4 (a) and (b) explain other examples of this invention. Although produced like Example 1, an active layer is constituted as follows. The active layer 15 shown in drawing 3 is taken as the compensates distortion multiple quantum well structure active layer which consists of three layers of undoped GaInP quantum well layers at 5 nm of 10 nm of thickness one side one side at the undoped tensile strain AlGaInAsP quantum barrier layer of four layers, and 5 nm in thickness by a undoped AlGaInP light separating confining layer and 4 nm in thickness. The outline about the forbidden band an active layer and near the active layer becomes like drawing 4. When the abnormal-conditions dope of the p type impurity could be carried out and a p type impurity was doped, the electron hole carrier concentration of $5x10^{17}$ – the $2x10^{18}cm^{-3}$ range was made to set to a tensile strain AlGaInAsP quantum barrier layer, without diffusing a p type impurity notably. Others obtain the element of drawing 3 completely like Example 1.

[0016]Since according to this example the above-mentioned high carrier concentration can be fixed in addition to increasing the barrier height of a lightguide when the abnormal-conditions dope of the p type impurity is carried out at a tensile strain AlGaInAsP quantum barrier layer as Example 1 showed, It was possible to have raised the electron hole carrier density poured in into a distortion quantum well layer. Thereby, generating of a profit is performed efficiently and differential gain increases. Since threshold

carrier density decreased, the improvement of low threshold current operation and characteristic temperature became still more possible. As a result, in this element, the threshold current of the room temperature could be reduced by 30-40 mA, and, as for characteristic temperature, 140-160K were obtained. In the reliability trial, at the temperature of 70 **, 50-mW constant optical power operation continued for 5000 hours or more, and it has attained.
[0017](Example 3) Drawing 5 and drawing 6 (a) and (b) explain other examples of this invention. Although produced like Example 2, an active layer is constituted as follows. The active layer 16 shown in drawing 5 considers it as the compensates distortion multiple quantum well structure active layer which consists of three layers of undoped GaInP quantum well layers at 5 nm of 10 nm of thickness one side one side at the undoped tensile strain AlGaInP quantum barrier layer of four layers, and 5 nm in thickness by a undoped AlGaInP light separating confining layer and 3 nm in thickness, A 0.5-nm-thick AlGaInAsP distorted interlayer is introduced into the both sides of a tensile strain AlGaInP quantum barrier layer. Let an AlGaInAsP distorted interlayer's deformation amount be a middle value of the deformation amount in a quantum well layer and a quantum barrier layer. The outline about the forbidden band an active layer and near the active layer becomes like drawing 6. The AlGaInAsP distorted interlayer was made to set up the electron hole carrier concentration of $5x10^{17}$ - the $2x10^{18} cm^{-3}$ range, without diffusing a p type impurity notably, when the abnormal-conditions dope of the p type impurity could be carried out and a p type impurity was doped. Others obtain the element of drawing 5 completely like Example 2.
[0018]Since according to this example in addition to the characteristic in the element of Example 1 the abnormal-conditions dope of the p type impurity is carried out at an AlGaInAsP distorted interlayer and the above-mentioned high carrier concentration can be fixed, an improvement of low threshold current operation and characteristic temperature is possible like Example 2. By the AlGaInAsP distorted interlayer, since the interface of a quantum well layer and a quantum barrier layer was made to ease the big distortion stress which works to a counter direction, the crystallinity of the whole distortion compensation amount child well structure has been improved greatly, and the luminescence intensity from an active layer was raised to 20 to 30 or more times. As a result, in this element, the threshold current of the room temperature could be reduced to 20-30 mA, and, as for characteristic temperature, 150-170K were obtained. In the reliability trial, at the temperature of 70 **, 60-mW constant optical power operation continued for 5000 hours or more, and it has attained.
[0019](Example 4) Other examples of this invention are described using drawing 5. A n type GaAs substrate with A plane direction is used for the substrate 1 in drawing 5 (511), At 0.5 micrometer in thickness, on it by the carrier concentration 1 - n type GaAs buffer layer 2 of $2x10^{18} cm^{-3}$, and 2.0 micrometers in thickness Carrier concentration $5x10^{17}$ - the n type AlGaInP lightguide 3 of $1x10^{18} cm^{-3}$, it consists of four layers of undoped GaInP compressive strain quantum well layers at 5 nm of 10 nm of thickness one side one side at the undoped tensile strain AlGaInP quantum barrier layer of five layers, and 4 nm in thickness by a undoped AlGaInP light separating confining layer and 3 nm in thickness — it providing compensates distortion multiple quantum well structure active layer 16, and, The 0.5-nm-thick AlGaInAsP distorted interlayer is introduced into the both sides of a tensile strain AlGaInP quantum barrier layer. After that, the element section equivalent to drawing 5 is obtained by producing an element completely like Example 3.
[0020]According to this example, threshold current and characteristic temperature have been improved 20 to 30% by the effect to the same element characteristic as Example 3. In this element, the oscillation wavelength 650 nm band was obtained, the threshold current of a room temperature is 30-40 mA, and, as for characteristic temperature, 130-150K were attained. In the reliability trial, at the temperature of 70 **, 50-mW constant optical power operation continued for 5000 hours or more, and it has attained.
[0021](Example 5) Other examples of this invention are described using drawing 5. A n type GaAs substrate with A plane direction is used for the substrate 1 in drawing 5 (511), At 0.5 micrometer in thickness, on it by the carrier concentration 1 - n type GaAs buffer layer 2 of $2x10^{18} cm^{-3}$, and 2.0 micrometers in thickness Carrier concentration $5x10^{17}$ - the n type AlGaInP lightguide 3 of $1x10^{18} cm^{-3}$, The compensates distortion multiple quantum well structure active layer 16 which consists of three layers of undoped GaInP tensile strain quantum well layers at 5 nm of 10 nm of thickness one side one side at the undoped compressive strain AlGaInP quantum barrier layer of four layers and 7 nm in

thickness by a undoped AlGaInP light separating confining layer and 3 nm in thickness is formed, The 0.5-nm-thick AlGaInAsP distorted interlayer is introduced into the both sides of a compressive strain AlGaInP quantum barrier layer. After that, the element section equivalent to drawing 5 is obtained by producing an element completely like Example 3 or 4.

[0022]According to this example, threshold current and characteristic temperature have been improved 20 to 30% by the effect to the same element characteristic as Example 3. In this element, the oscillation wavelength 630 nm band was obtained, the threshold current of a room temperature is 40-50 mA, and, as for characteristic temperature, 110-130K were attained. In the reliability trial, at the temperature of 70 **, 40-mW constant optical power operation continued for 5000 hours or more, and it has attained.

[0023](Example 6) Other examples of this invention are described using drawing 5. A n type InP substrate is used for the substrate 1 in drawing 5, moreover -- 0.5 micrometer in thickness. Come out and The carrier concentration 1 - the n type InP buffer layer 2 of 2x10 ^{18}cm^{-3}, 2.0 micrometers in thickness. Come out and Carrier concentration 5x10 ^{17} - the n type InP lightguide 3 of 1x10 ^{18}cm^{-3}, It becomes the active layer 16 from four layers of undoped GaInAsP compressive strain quantum well layers at 20 nm of 40 nm of thickness one side one side at the undoped tensile strain GaInAsP quantum barrier layer of five layers, and 6 nm in thickness by a undoped GaInAsP light separating confining layer and 5 nm in thickness, The compensates distortion multiple quantum well structure active layer which introduced the 0.5-nm-thick GaInAsP distorted interlayer is provided in the both sides of a tensile strain GaInAsP quantum barrier layer, further -- 0.022 micrometer in thickness. Come out and by the carrier concentration 2 - the p type InP lightguide 5 of 4x10 ^{17}cm^{-3}, and 1.15 nm of thickness 4 atomic layers Five layers of p type GaInAsP well layers and 1.5 nm of thickness pentatomic layers of carrier concentration 5x10 ^{17} - 1x10 ^{18}cm^{-3}. The superstructure high carrier concentration layer 6 and 0.24 micrometer in thickness which come out and consist of the carrier concentration 2 - four layers of p type InP barrier layers of 4x10 ^{17}cm^{-3} The carrier concentration 2 - the p type InP lightguide 7 of 5x10 ^{17}cm^{-3}, They are the carrier concentration 5 - the p type GaInAsP etching stopping layer 8 of 8x10 ^{17}cm^{-3}, and 1.4 micrometers in thickness at 0.01 micrometer in thickness. Carrier concentration 8x10 ^{17} - the p type InP lightguide 9 of 1x10 ^{18}cm^{-3}, The p type GaInAsP buffer layer 10 of carrier concentration 8x10 ^{17} - 2x10 ^{18}cm^{-3} is grown epitaxially by an organic-metal-vapor-growth (MOCVD) method at 0.02-0.05 micrometer in thickness.

[0024]The outline about the forbidden band an active layer and near the active layer becomes like drawing 6.

[0025]Next, the stripe mask of a SiO_2 insulator layer is formed by vapor-depositing a SiO_2 insulator layer and passing through photo lithography and an etching process. Carrying out etching removal of the layers 10 and 9 using a SiO_2 insulator layer mask, until it results in the layer 8, the trapezoid shown in drawing 5 produces the reverse mesa-like ridge stripe in which the length of the neighborhood of the upper part and the lower part became reverse. Then, selective growth of the carrier concentration 1 - the n type InP embedding current stricture layer 11 of 3x10 ^{18}cm^{-3} is carried out at 0.6-1.2 micrometers in thickness, After carrying out etching removal of the SiO_2 insulator layer mask, the p type GaInAs embedding contact layer 12 of carrier concentration 1x10 ^{18} - 1x10 ^{19}cm^{-3} is grown up at 1-2 micrometers in thickness. After vapor-depositing the p lateral electrode 13 and the n lateral electrode 14, a cleavage scribe is carried out and the element section equivalent to drawing 5 is obtained.

[0026]According to this example, threshold current and characteristic temperature have been improved 20 to 30% by the effect to the same element characteristic as Example 3. At this element, it is an oscillation wavelength of 1.3 micrometers. The belt was obtained, the threshold current of a room temperature is 15-25 mA, and, as for characteristic temperature, 80-100K were attained. By a reliability trial, 20-mW constant optical power operation is 20000 at the temperature of 85 **. Beyond time continued and it has attained.

[0027]

[Effect of the Invention]According to this invention, even if it used the mixed-crystal semiconductor material in which V group element for which precise control of the electron hole carrier concentration

setting level of a p type impurity was difficult until now makes a phosphorus system a subject, it became possible to provide the semiconductor laser provided with the stable element characteristic which is not notably influenced in diffusion of a p type impurity. Since the activated hole concentration can be set as the high level of $1 \times 10^{18} cm^{-3}$, without diffusing a p type impurity, the large energy barrier height of a p type lightguide can be taken 40 to 65 meV. Since the increase in this barrier height will control the leakage of the career from an active layer, reduction of threshold current and an improvement of high temperature operation are brought about.

[0028]As a result, it was possible to have raised threshold current and characteristic temperature 20 to 30% in a laser device. In short wavelength 680 nm-band AlGaInP laser, the threshold current of a room temperature is 20-30 mA, and, as for characteristic temperature, 150-170K were obtained. In the reliability trial, in 70 **, 60-mW constant optical power operation continued for 5000 hours or more, and it has attained. Long wavelength of 1.3 micrometers In belt InP laser, the threshold current of a room temperature is 15-25 mA, and, as for characteristic temperature, 80-100K were obtained. In the reliability trial, at the temperature of 85 **, 20-mW constant optical power operation continued for 20000 hours or more, and it has attained.

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* NOTICES *

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1]Drawing of longitudinal section of the element in one example of this invention.
[Drawing 2]The forbidden-band schematic diagram of the active layer in the element of one example of this invention, and a lightguide.
[Drawing 3]Drawing of longitudinal section of the element in other examples of this invention.
[Drawing 4]The forbidden-band schematic diagram of the active layer in the element of other examples of this invention, and a lightguide.
[Drawing 5]Drawing of longitudinal section of the element in the example of further others of this invention.
[Drawing 6]The forbidden-band schematic diagram of the active layer in the element of the example of further others of this invention, and a lightguide.
[Description of Notations]
1 [-- Compensates distortion multiple quantum well structure active layer,] -- A n type substrate, 2 -- A n type buffer layer, 3 -- A n type lightguide, 4 5 -- A p type lightguide, 6 -- AlGaInAsP or GaInAsP multi-cycle superstructure high carrier concentration layer, 7 -- A p type lightguide, 8 -- A p type etching stopping layer, 9 -- P type lightguide, 10 -- A p type buffer layer, 11 -- A n type embedding current stricture layer, 12 -- P type embedding contact layer, 13 [-- Compensates distortion multiple quantum well structure active layer which introduced the AlGaInAsP or GaInAsP distorted interlayer.] -- p lateral electrode, 14 -- n lateral electrode, 15 -- The compensates distortion multiple quantum well structure active layer, 16 which introduced AlGaInAsP or a GaInAsP quantum barrier layer

[Translation done.]

(19)日本国特許庁（ＪＰ）　(12) 公開特許公報(A)　(11)特許出願公開番号

特開平10－290049

(43)公開日　平成10年(1998)10月27日

(51)Int.Cl.[6]　識別記号　ＦＩ

Ｈ０１Ｓ　3/18　Ｈ０１Ｓ　3/18

Ｈ０１Ｌ　29/06　Ｈ０１Ｌ　29/06

審査請求　未請求　請求項の数12　ＯＬ　（全　７　頁）

(21)出願番号　特願平9－96918

(22)出願日　平成９年(1997)４月15日

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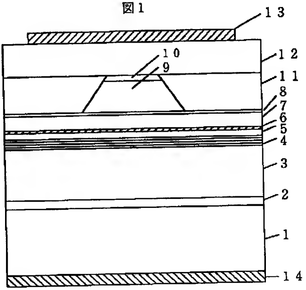
(54)【発明の名称】　半導体レーザ素子

(57)【要約】

【課題】ｐ型不純物の正孔キャリア濃度レベルを適切に設定し、不純物拡散を抑制する。

【解決手段】半導体レーザ素子の活性層４近傍のｐ型のＡｌＧａＩｎＰ光導波層中に、拡散定数が小さくキャリア濃度を拡散させずに5×10^{17}～1×10^{18} cm^{-3}の範囲を設定できるｐ型ＩｎＧａＡｓＰ層を導入する。ＩｎＧａＡｓＰ層は、ＡｌＧａＩｎＰ光導波層よりも禁制帯幅が小さくなるので、薄膜層として多周期超格子層構造を構成する。

図１



【特許請求の範囲】

【請求項１】Ｖ族元素として燐系を主体とする半導体結晶層の中に、Ｖ族元素に砒素系を導入した半導体結晶層を設けてあり、Ｖ族元素が砒素系である半導体層は量子サイズ効果を生ずる薄膜層として或いは薄膜層からなる多周期超格子構造として設けてあることを特徴とする半導体レーザ素子。

【請求項２】Ｖ族元素として燐系を主体とする半導体結晶層の中に、Ｖ族元素に砒素系を導入した半導体結晶層を設けてあり、かつＶ族元素を燐系とした半導体層中よりもＶ族元素が砒素系である半導体層において、不純物のキャリア濃度を高く設定してあることを特徴とする請求項１に記載の半導体レーザ素子。

【請求項３】III －Ｖ族混晶半導体材料のうちＶ族元素に燐系を主体とする材料を用いて、半導体発光活性層とそれを挟む半導体光導波層からなる二重ヘテロ接合構造を形成しており、Ｖ族元素が燐系である上記光導波層中における上記活性層近傍に対して多周期超格子層を設けておき、少なくとも超格子井戸層はＶ族元素に砒素系を導入した層により形成してあり、さらに上記超格子井戸層には上記光導波層よりも不純物のキャリア濃度を高く設定してあることを特徴とする請求項１または２に記載の半導体レーザ素子。

【請求項４】上記発光活性層は歪量子井戸層と歪量子障壁層を繰り返した歪多重量子井戸構造として設けておき、Ｖ族元素が砒素系である半導体結晶層により歪量子井戸層と隣接する歪量子障壁層や光分離閉じ込め層を形成し、かつ砒素系からなる上記歪量子障壁層や光分離閉じ込め層に不純物をドープしてあることを特徴とする請求項３に記載の半導体レーザ素子。

【請求項５】上記光導波層や上記発光活性層に導入した少なくともＶ族元素を砒素系として設けた層には不純物としてｐ型の導電型を示す不純物をドープし、不純物ドープにより活性化した正孔キャリア濃度を設定してあることを特徴とする請求項３または４に記載の半導体レーザ素子。

【請求項６】上記光導波層中に設けた超格子構造を構成する、Ｖ族元素を砒素系とした超格子井戸層にはｐ型不純物をドープして活性化した正孔キャリア濃度を上記光導波層よりも高く設定してあり、正孔キャリア濃度を3×10^{17}～1×10^{19} cm^{-3}の範囲、より適切には5×10^{17}～5×10^{18} cm^{-3}の範囲に設定してあることを特徴とする請求項３または５に記載の半導体レーザ素子。

【請求項７】上記発光活性層を構成する歪多重量子井戸構造の中で、Ｖ族元素を砒素系とした歪量子障壁層や光分離閉じ込め層に対してｐ型不純物をドープすることにより、活性化した正孔キャリア濃度を1×10^{17}～5×10^{18} cm^{-3}の範囲より適切には3×10^{17}～2×10^{18} cm^{-3}の範囲に設定して、変調ドープしてある歪多重量子井戸構造を構成していることを特徴とする請求項４または６に記載の半導体レーザ素子。

【請求項８】上記発光活性層を歪量子井戸層及び上記歪量子井戸層とは反対符号の格子歪を有する歪量子障壁層との繰り返しによる歪補償多重量子井戸構造とし、上記歪量子井戸層と上記歪量子障壁層の間にそれぞれの中間の格子歪量を有した歪中間層を設け、上記歪中間層をＶ族元素が砒素系からなる層により形成することにより構成してあることを特徴とする請求項１に記載の半導体レーザ素子。

【請求項９】上記歪量子井戸層と上記歪量子障壁層の間に設けた砒素系からなる歪中間層に対して、不純物としてｐ型の導電型を示す不純物をドープし、不純物ドープにより活性化した正孔キャリア濃度を設定してあることを特徴とする請求項８に記載の半導体レーザ素子。

【請求項１０】上記歪中間層に対してｐ型不純物をドープすることにより、活性化した正孔キャリア濃度を1×10^{17}～5×10^{18} cm^{-3}の範囲より適切には3×10^{17}～2×10^{18} cm^{-3}の範囲に設定して、変調ドープしてある歪補償多重量子井戸構造を構成していることを特徴とする請求項９に記載の半導体レーザ素子。

【請求項１１】ｐ型導電型を示す不純物としてドープする元素種類は、Ｚｎ，Ｍｇ或いはＢｅであり、これらいずれかの元素をドープすることにより活性化した正孔キャリア濃度を設定してあることを特徴とする請求項１から１０に記載の半導体レーザ素子。

【請求項１２】上記光導波層や上記発光活性層を設けるのに用いる単結晶基板は（１００）面からオフした面方位を有しており、面方位は（１００）面から０～５４．７°　の範囲より適切には５～２５．２°　の範囲であり、実際的に最適な範囲として７～１６°に設定してあり、上記単結晶基板上に形成してあることを特徴とする請求項１に記載の半導体レーザ素子。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、光情報処理或いは光計測用の光源に適する半導体レーザ素子に関する。

【０００２】

【従来の技術】従来技術では、半導体レーザの光導波層にドープしたｐ型不純物が拡散しやすく、さらに所望のキャリア濃度を設定し難いという状況にあり、素子特性の改善が図れないという問題を有していた。従来例ではエレクトロニクス・レターズ１９９６年３２巻６６１－６６２頁（Electronics Letters　１９９６，３２，６６１－６６２）に示されているように、ｐ型不純物として亜鉛を例として、１．３μm 帯の長波長半導体レーザではｐ型キャリア濃度を光導波層に対して2×10^{18} cm^{-3}以上、活性層に対して5×10^{17} cm^{-3}以上導入すると、閾値電流や微分量子効率等の素子特性が劣化してくることを報告している。

【０００３】

【発明が解決しようとする課題】上記従来技術では、長波長帯のＩｎＰ系レーザ素子において、拡散しやすいｐ型不純物の素子特性に対する影響を調べた内容であり、顕著に影響しないｐ型キャリア濃度の実験的なレベルを評価した結果を述べているだけである。しかしながら、拡散を抑制したりｐ型キャリア濃度を高いレベルに制御するための新規な手法については述べていない。

【０００４】本発明の目的は、半導体レーザの素子特性、特に閾値電流や温度特性の改善を図るため、光導波層や活性層に対して高いキャリア濃度を設定する手法について内容を言及する。特に、Ｖ族元素が燐系からなる半導体材料では、ｐ型不純物の拡散により活性化したキャリア濃度を制御し難いという課題に対して解決手段を示すことにより、素子特性の向上を実現することにある。

【０００５】

【課題を解決するための手段】本発明では、混晶半導体でＶ族元素が主に燐系で構成されている半導体レーザ素子に対して、上記課題を解決する手段を述べる。Ｖ族元素が燐系で構成される半導体レーザでは、ｐ型不純物が拡散しやすいという特徴を有しているため、正孔キャリア濃度を10^{18} cm^{-3}近くのオーダと高く設計できず、素子特性上で不純物の拡散が問題とならない10^{17} cm^{-3}の低い値に設定しておかなければならないという制約がある。特に、短波長帯の半導体レーザに用いられるＡｌＧａＩｎＰ系材料では、ｐ型不純物濃度が10^{17} cm^{-3}オーダの値であるときにも成長条件等の外部環境条件次第では拡散が生じるために、非常に精密なキャリア濃度の設定が要求される。

【０００６】このため、本発明ではｐ型不純物の拡散定数が小さい材料としてＶ族元素の砒素系からなる材料を用いて、拡散を抑制し、かつ所定のキャリア濃度を狭い領域に設定できるようにした。Ｖ族元素に砒素を導入した材料では、ｐ型不純物の拡散定数を一桁から二桁近く小さくすることができる。ＡｌＧａＩｎＡｓＰ又はＧａＩｎＡｓＰ系材料を用いて砒素の組成を適切に調整することにより、長波長系材料のＩｎＰ系や禁制帯幅が大きく短波長系材料のＡｌＧａＩｎＰ系に対しても、格子定数を合わせながら導入可能である。

【０００７】素子に対しては、ｐ型光導波層の正孔キャリア濃度を活性層近傍により高く設定できることにより、価電子帯におけるフェルミレベルを高くでき、エネルギー障壁高さを増大させた設計が可能となる。ｐ型光導波層の障壁高さの増大により、活性層からの電子キャリアの漏れを抑制できる。素子特性では、閾値電流を低減し特に温度特性を改善することに多大の効果を発現させ、上記特性を少なくとも２０～３０％向上させることができた。

【０００８】本発明の半導体レーザ素子の特徴をある限定された局面から記載すれば、発光領域たる活性層又は多重量子井戸構造を有する活性領域に隣接した半導体領域（活性領域より小さい屈折率を有する）のうち、ｐ型の導電性を有する部分に第１の半導体層と第２の半導体層とを繰り返して積層してなる積層構造を導入する。いずれの半導体層もIII 族元素とＶ族元素からなる化合物半導体層で形成されるが、これらの化合物半導体層を構成するＶ族元素の組成比において第２の半導体層は第１半導体層より高い比率のＡｓ（砒素）を含み、又は第１半導体層は第２半導体層より高い比率のＰ（燐）を含むところに第一の特徴がある。第１の半導体層と第２の半導体層とが夫々の半導体層内に格子不整合による転位を生じさせない限りにおいては、第１の半導体層がＡｓを含まないことや、また第２の半導体層がＰを含まないことが許容される。第二の特徴としては、上記第２の半導体層のｐ型不純物濃度が上記第１の半導体層のそれより高いことにある。上述の半導体領域に要請される抵抗値に応じては、第１の半導体層に人為的にｐ型不純物を導入しなくても（所謂アンドープとしても）よい。

【０００９】これらの半導体層は、量子サイズ効果をもたらす観点から望ましくは厚みを１０ｎｍ以下とする（積層構造を超格子とする）ことがよく、この場合、例えば第２半導体層が発光領域より高い屈折率を示したとしても、発光領域に対する実効的な屈折率は積層構造全体のマクロな値となり、発光領域の屈折率の方が高くなるので光閉じ込め又は光導波に何ら支障を来さない利点がある。なお、上述の半導体領域とは、クラッド層又はクラッド層より屈折率が高くかつ発光領域寄りに設けられる光ガイド層を指す。上述の積層領域は、ｐ型導電部の内部に設けても、またｐ型導電部とアンドープ部（人為的に不純物を導入しない部分）との境界に設けてもよい。

【００１０】

【発明の実施の形態】以下、本発明の望ましき実施形態を示した実施例１乃至６とその関連図面より、本発明を具体的に説明する。

【００１１】（実施例１）本発明の一実施例について図１を用いて説明する。図１中のｎ型ＧａＡｓ基板１上に、厚さ0.5μm でキャリア濃度１～2×10^{18} cm^{-3}のｎ型ＧａＡｓバッファ層２，厚さ2.0μm でキャリア濃度5×10^{17}～1×10^{18} cm^{-3}のｎ型ＡｌＧａＩｎＰ光導波層３，厚さ片側２０ｎｍ片側１０ｎｍでアンドープＡｌＧａＩｎＰ光分離閉じ込め層と厚さ４ｎｍでアンドープ引張歪ＡｌＧａＩｎＰ量子障壁層２層及び厚さ５ｎｍでアンドープＧａＩｎＰ圧縮歪量子井戸層３層からなる歪補償多重量子井戸構造活性層４，厚さ0.022μm でキャリア濃度２～4×10^{17} cm^{-3}のｐ型ＡｌＧａＩｎＰ光導波層５，厚さ４原子層1.15ｎｍでキャリア濃度5×10^{17}～1×10^{18} cm^{-3}のｐ型ＧａＩｎＡｓＰ井戸層５層と厚さ５原子層1.5ｎｍ でキャリア濃度２～4×10^{17} cm^{-3}のｐ型ＡｌＧａＩｎＰ障壁層４層か

らなる超格子構造高キャリア濃度層6，厚さ0.24μmでキャリア濃度2～5×10^{17} cm^{-3} のp型AlGaInP光導波層7，厚さ0.01μmでキャリア濃度5～8×10^{17} cm^{-3} のp型GaInPエッチング停止層8，厚さ1.35μm でキャリア濃度8×10^{17} ～1×10^{18} cm^{-3} のp型AlGaInP光導波層9，厚さ0.02～0.05μmでキャリア濃度8×10^{17} ～2×10^{18} cm^{-3} のp型GaInPバッファ層10を有機金属気相成長（MOCVD）法によりエピタキシャル成長する。

【0012】活性層と活性層近傍の禁制帯に関する概略は図2（a)，（b）のようになる。

【0013】次に、SiO_2 絶縁膜を蒸着し、ホトリソグラフィーとエッチング工程を経ることにより、SiO_2 絶縁膜のストライプマスクを形成する。SiO_2 絶縁膜マスクを利用して、層10と9を層8に到るまでエッチング除去して、図1に示す台形状の順メサリッジストライプを作製する。その後、厚さ0.6～1.2μmでキャリア濃度1～3×10^{18} cm^{-3} のn型GaAs埋め込み電流狭窄層11を選択成長し、SiO_2 絶縁膜マスクをエッチング除去した後、厚さ3～5μmでキャリア濃度1×10^{18} ～1×10^{20} cm^{-3} のp型GaAs埋め込みコンタクト層12を成長する。さらに、p側電極13，n側電極14を蒸着した後、劈開スクライブして、図1の素子を得る。

【0014】本実施例によると、活性層近傍においてInGaAsP超格子構造の高キャリア濃度層を設けることにより、p型不純物を顕著に拡散させずに5×10^{17} ～1×10^{18} cm^{-3} 範囲の正孔キャリア濃度を設定させることができた。これは、p型AlGaInP光導波層中における従来設定可能であった値の3～5倍のレベルに相当する。正孔キャリア濃度が1×10^{17} cm^{-3} レベルである場合と比較すると、価電子帯におけるフェルミレベルを高く設定でき、p型光導波層のエネルギー障壁高さは少なくとも40meVから65meV程度さらに増大させたことになる。この障壁高さの増大により、活性層からの電子キャリアの漏れを抑制できるので、閾値電流を低減し、さらに温度特性を改善することが可能となった。その結果、閾値電流と特性温度を20～30%改善できた。本素子では、波長680nm帯で発振し、室温の閾値電流は40～50mAであり、特性温度は130～150Kが得られた。信頼性試験では、温度70℃において40mWの定光出力動作が5000時間以上継続して達成できた。

【0015】（実施例2）本発明の他の実施例を図3及び図4（a)，（b）により説明する。実施例1と同様に作製するが、活性層を以下のように構成する。図3に示す活性層15は、厚さ片側10nm片側5nmでアンドープAlGaInP光分離閉じ込め層と厚さ4nmでアンドープ引張歪AlGaInAsP量子障壁層4層及び厚さ5nmでアンドープGaInP量子井戸層3層からなる歪補償多重量子井戸構造活性層とする。活性層と活性層近傍の禁制帯に関する概略は図4のようになる。引張歪AlGaInAsP量子障壁層には、p型不純物を変調ドープしてもよく、p型不純物をドープした場合には、p型不純物を顕著に拡散させずに5×10^{17} ～2×10^{18} cm^{-3} 範囲の正孔キャリア濃度を設定させた。その他は、実施例1と全く同様にして図3の素子を得る。

【0016】本実施例によると、実施例1で示したように、光導波層の障壁高さを増大させることに加えて、引張歪AlGaInAsP量子障壁層にp型不純物を変調ドープした場合に上記の高いキャリア濃度を固定できるので、歪量子井戸層中へ注入する正孔キャリア密度を向上させることが可能であった。これにより、利得の発生が効率良く行われ、微分利得が増大する。閾キャリア密度が減少するので、低閾値電流動作と特性温度の改善がさらに可能となった。その結果、本素子では、室温の閾値電流を30～40mA低減でき、特性温度は140～160Kが得られた。信頼性試験では、温度70℃において50mWの定光出力動作が5000時間以上継続して達成できた。

【0017】（実施例3）本発明の他の実施例を図5及び図6（a)，（b）により説明する。実施例2と同様に作製するが、活性層を以下のように構成する。図5に示す活性層16は、厚さ片側10nm片側5nmでアンドープAlGaInP光分離閉じ込め層と厚さ3nmでアンドープ引張歪AlGaInP量子障壁層4層及び厚さ5nmでアンドープGaInP量子井戸層3層からなる歪補償多重量子井戸構造活性層とし、引張歪AlGaInP量子障壁層の両側には、厚さ0.5nm のAlGaInAsP 歪中間層を導入する。AlGaInAsP歪中間層の歪量は、量子井戸層と量子障壁層における歪量の中間の値とする。活性層と活性層近傍の禁制帯に関する概略は図6のようになる。AlGaInAsP歪中間層には、p型不純物を変調ドープしてもよく、p型不純物をドープした場合には、p型不純物を顕著に拡散させずに5×10^{17} ～2×10^{18} cm^{-3} 範囲の正孔キャリア濃度を設定させた。その他は、実施例2と全く同様にして図5の素子を得る。

【0018】本実施例によると、実施例1の素子における特性に加えて、AlGaInAsP歪中間層にp型不純物を変調ドープして上記の高いキャリア濃度を固定できるので、実施例2と同様に、低閾値電流動作と特性温度の改善が可能である。さらに、AlGaInAsP歪中間層によって、量子井戸層と量子障壁層の界面に反対方向に働く大きな歪応力を緩和させることができるので、歪補償量子井戸構造全体の結晶性を大きく改善し、活性層からの発光強度を20～30倍以上に向上させた。その結果、本素子では、室温の閾値電流を20～30mAに低減でき、特性温度は150～170Kが得られた。

信頼性試験では、温度７０℃において６０mWの定光出力動作が５０００時間以上継続して達成できた。

【００１９】（実施例４）本発明の他の実施例について図５を用いて説明する。図５中の基板１には（５１１）A面方位を有したｎ型ＧａＡｓ基板を用いて、その上に厚さ０．５μmでキャリア濃度１～２×１０^{18} cm^{-3} のｎ型ＧａＡｓバッファ層２，厚さ２．０μmでキャリア濃度５×１０^{17} ～１×１０^{18} cm^{-3}のｎ型ＡｌＧａＩｎＰ光導波層３，厚さ片側１０ｎm片側５ｎmでアンドープＡｌＧａＩｎＰ光分離閉じ込め層と厚さ３ｎmでアンドープ引張歪ＡｌＧａＩｎＰ量子障壁層５層及び厚さ４ｎmでアンドープＧａＩｎＰ圧縮歪量子井戸層４層からなる歪補償多重量子井戸構造活性層１６設け、引張歪ＡｌＧａＩｎＰ量子障壁層の両側には、厚さ０．５ｎmのＡｌＧａＩｎＡｓＰ歪中間層を導入している。その後は、実施例３と全く同様にして、素子を作製することにより、図５に相当する素子断面を得る。

【００２０】本実施例によると、実施例３と同様な素子特性への効果により、閾値電流と特性温度を２０～３０％改善できた。本素子では、発振波長６５０ｎm帯が得られ、室温の閾値電流は３０～４０mAであり、特性温度は１３０～１５０Kが達成された。信頼性試験では、温度７０℃において５０mWの定光出力動作が5000時間以上継続して達成できた。

【００２１】（実施例５）本発明の他の実施例について図５を用いて説明する。図５中の基板１には（５１１）A面方位を有したｎ型ＧａＡｓ基板を用いて、その上に厚さ０．５μmでキャリア濃度１～２×１０^{18} cm^{-3} のｎ型ＧａＡｓバッファ層２，厚さ２．０μmでキャリア濃度５×１０^{17} ～１×１０^{18} cm^{-3}のｎ型ＡｌＧａＩｎＰ光導波層３，厚さ片側１０ｎm片側５ｎmでアンドープＡｌＧａＩｎＰ光分離閉じ込め層と厚さ３ｎmでアンドープ圧縮歪ＡｌＧａＩｎＰ量子障壁層４層及び厚さ７ｎmでアンドープＧａＩｎＰ引張歪量子井戸層３層からなる歪補償多重量子井戸構造活性層１６を設け、圧縮歪ＡｌＧａＩnP量子障壁層の両側には、厚さ０．５ｎmのＡｌＧａＩｎＡｓＰ歪中間層を導入している。その後は、実施例３や４と全く同様にして、素子を作製することにより、図５に相当する素子断面を得る。

【００２２】本実施例によると、実施例３と同様な素子特性への効果により、閾値電流と特性温度を２０～３０％改善できた。本素子では、発振波長６３０ｎm帯が得られ、室温の閾値電流は４０～５０mAであり、特性温度は１１０～１３０Kが達成された。信頼性試験では、温度７０℃において４０mWの定光出力動作が5000時間以上継続して達成できた。

【００２３】（実施例６）本発明の他の実施例について図５を用いて説明する。図５中の基板１にはｎ型ＩｎＰ基板を用いて、その上に厚さ０．５μm でキャリア濃度１～２×１０^{18} cm^{-3}のｎ型ＩｎＰバッファ層２，厚さ２．０μm でキャリア濃度５×１０^{17} ～１×１０^{18} cm^{-3}のｎ型ＩｎＰ光導波層３，活性層１６には厚さ片側４０ｎm片側２０ｎmでアンドープＧａＩｎＡｓＰ光分離閉じ込め層と厚さ５ｎmでアンドープ引張歪ＧａＩｎＡｓＰ量子障壁層５層及び厚さ６ｎmでアンドープGaInAsP圧縮歪量子井戸層４層からなり、引張歪ＧａＩｎＡｓＰ量子障壁層の両側には厚さ０．５ｎm のＧａＩｎＡｓＰ歪中間層を導入した歪補償多重量子井戸構造活性層を設け、さらに厚さ０．０２２μm でキャリア濃度２～４×１０^{17} cm^{-3}のｐ型ＩｎＰ光導波層５，厚さ４原子層１．１５ｎmでキャリア濃度５×１０^{17} ～１×１０^{18} cm^{-3}のｐ型ＧａＩｎＡｓＰ井戸層５層と厚さ５原子層１．５ｎm でキャリア濃度２～４×１０^{17} cm^{-3}のｐ型ＩｎＰ障壁層４層からなる超格子構造高キャリア濃度層６，厚さ０．２４μm でキャリア濃度２～５×１０^{17} cm^{-3}のｐ型ＩｎＰ光導波層７，厚さ０．０１μmでキャリア濃度５～８×１０^{17} cm^{-3} のｐ型ＧａＩｎＡｓＰエッチング停止層８，厚さ１．４μm でキャリア濃度８×１０^{17} ～１×１０^{18} cm^{-3}のｐ型ＩｎＰ光導波層９，厚さ０．０２～０．０５μmでキャリア濃度８×１０^{17} ～２×１０^{18} cm^{-3}のｐ型ＧａＩｎＡｓＰバッファ層１０を有機金属気相成長（MOCVD）法によりエピタキシャル成長する。

【００２４】活性層と活性層近傍の禁制帯に関する概略は図６のようになる。

【００２５】次に、ＳｉO_2 絶縁膜を蒸着し、ホトリソグラフィーとエッチング工程を経ることにより、ＳｉO_2 絶縁膜のストライプマスクを形成する。ＳｉO_2 絶縁膜マスクを利用して、層１０と９を層８に到るまでエッチング除去して、図５に示す台形とは上部と下部の辺の長さが逆になった逆メサ状のリッジストライプを作製する。その後、厚さ０．６～１．２μmでキャリア濃度１～３×１０^{18} cm^{-3}のｎ型ＩｎＰ埋め込み電流狭窄層１１を選択成長し、ＳｉO_2 絶縁膜マスクをエッチング除去した後、厚さ１～２μmでキャリア濃度１×１０^{18} ～１×１０^{19} cm^{-3}のｐ型ＧａＩｎＡｓ埋め込みコンタクト層１２を成長する。さらに、ｐ側電極１３，ｎ側電極１４を蒸着した後、劈開スクライブして、図５に相当する素子断面を得る。

【００２６】本実施例によると、実施例３と同様な素子特性への効果により、閾値電流と特性温度を２０～３０％改善できた。本素子では、発振波長１．３μm 帯が得られ、室温の閾値電流は１５～２５mAであり、特性温度は８０～１００Kが達成された。信頼性試験では、温度８５℃において２０mWの定光出力動作が20000 時間以上継続して達成できた。

【００２７】

【発明の効果】本発明によると、これまでｐ型不純物の正孔キャリア濃度設定レベルの精密な制御が困難であった、Ｖ族元素が燐系を主体とする混晶半導体材料を用い

ても、ｐ型不純物の拡散に顕著に影響されない安定した素子特性を備えた半導体レーザを提供することが可能となった。ｐ型不純物を拡散させずに、活性化した正孔濃度を１×１０^{18} cm^{-3} の高いレベルに設定できるようになるので、ｐ型光導波層のエネルギー障壁高さを４０～６５ｍｅＶ大きく取れる。この障壁高さの増加は、活性層からのキャリアの漏れを抑制することになるので、閾値電流の低減や高温動作の改善がもたらされる。

【００２８】その結果、レーザ素子では、閾値電流と特性温度を２０～３０％向上させることが可能であった。短波長６８０ｎｍ帯ＡｌＧａＩｎＰレーザでは、室温の閾値電流が２０～３０ｍＡであり、特性温度は１５０～１７０Ｋが得られた。信頼性試験では、７０℃において６０ｍＷの定光出力動作が５０００時間以上継続して達成できた。長波長１．３μｍ 帯ＩｎＰレーザでは、室温の閾値電流は１５～２５ｍＡであり、特性温度は８０～１００Ｋが得られた。信頼性試験では、温度８５℃において２０ｍＷの定光出力動作が２００００時間以上継続して達成できた。

【図面の簡単な説明】

【図１】本発明の一実施例における素子の縦断面図。 ＊

＊【図２】本発明の一実施例の素子における活性層及び光導波層の禁制帯概略図。

【図３】本発明の他の実施例における素子の縦断面図。

【図４】本発明の他の実施例の素子における活性層及び光導波層の禁制帯概略図。

【図５】本発明のさらに他の実施例における素子の縦断面図。

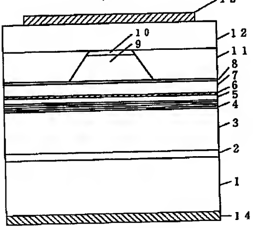
【図６】本発明のさらに他の実施例の素子における活性層及び光導波層の禁制帯概略図。

【符号の説明】

１…ｎ型基板、２…ｎ型バッファ層、３…ｎ型光導波層、４…歪補償多重量子井戸構造活性層、５…ｐ型光導波層、６…ＡｌＧａＩｎＡｓＰ又はＧａＩｎAsＰ多周期超格子構造高キャリア濃度層、７…ｐ型光導波層、８…ｐ型エッチング停止層、９…ｐ型光導波層、１０…ｐ型バッファ層、１１…ｎ型埋め込み電流狭窄層、１２…ｐ型埋め込みコンタクト層、１３…ｐ側電極、１４…ｎ側電極、１５…ＡｌＧａＩｎＡｓＰ又はＧａＩｎＡｓＰ量子障壁層を導入した歪補償多重量子井戸構造活性層、１６…ＡｌＧａＩｎＡｓＰ又はＧａＩｎＡｓＰ歪中間層を導入した歪補償多重量子井戸構造活性層。

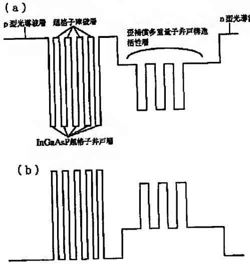
【図１】

図1



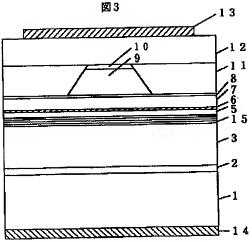
【図２】

図2



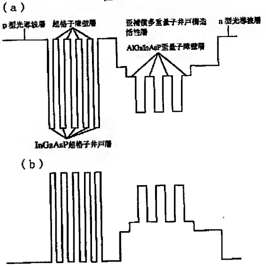
【図３】

図3



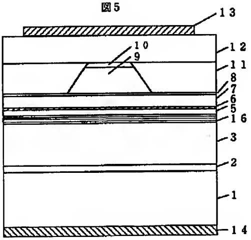
【図４】

図4



【図５】

図5



【図６】

図6